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THE COLLEGE OF AERONAUTICS

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STRENGTHS OF AVDEL LIGHT ALLOY BLIND RIVETS IN DTD 546 B SHEET

by

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The Double and Single Shear Strengths of Avdel[1] Light Alloy Blind Rivets in DTD 546 b Aluminium Alloy Sheet.

-by-

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SUMMARY

Tests have been performed to compare the double- and single-shear strengths of joints in DTD 546 b light alloy sheets using Avdel blind rivets. The tests were an extension of work done on solid rivets, and followed conventional procedures.

The double-shear proof and ultimate strengths were found to be appreciably better than the single-shear strengths over a useful range of sheet thickness/rivet diameter ratio.

The effect of manufacturing tolerance was examined and found to be important, though adherence to the rivet manufacturer's recommended procedures ensures good strength.

The above conclusions lead to a consideration of the physical behaviour of the joints which is seen to differ in three ranges of thickness/diameter ratio.

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SYMBOLS

A	cross-sectional area of a rivet
d	diameter of rivet
k_{10}	ratio of double-shear to equivalent single-shear strength for 1°/o proof case
k_{20}	ratio of double-shear to equivalent single-shear strength for 2°/o proof case
K	ratio of double-shear to equivalent single-shear strength for ultimate case
r_{10}	1°/o proof strength of joint (defined as that load producing a permanent extension of 2°/o of one rivet diameter)
r_{20}	2°/o proof strength of joint (defined as that load producing a permanent extension of 4°/o of one rivet diameter)
R	ultimate strength of joint
t	sheet thickness of plate of single-shear joint, or half the centre plate of the double-shear joint

Equivalent single- and double-shear joints have the same value of A/dt or d/t.

Introduction

A series of tests were recently performed by Howe[2] to investigate the double-shear strength of common snap-head rivet joints, and it was felt to be of interest to extend the work to a mandrel type rivet. Accordingly, a limited series of tests have been made, following the R.A.E. method[3], on the Avdel blind rivet.

Description of Tests

A range of single- and double-shear lap-joints of DTD 546 b sheet were tested with 1/8" and 5/32" diameter rivets, and sheet thicknesses from 10 to 26 swg. The specimens (Fig. 1) were identical to those used previously, having two rivets in line, and equal thickness of sheet, (the double-shear ones having two strips on each side of the joint). The rivets were used in accordance with the manufacturer's directions.

It was found to be of interest to check the effect of fit (of the rivet holes) on strength, so three tests were made on single-shear joints which were nominally identical, though in manufacture had been finished with different drill sizes.

Following these tests, a second series of tests were performed to check and augment the first set.

The tests were made in a Denison Testing Machine, using a dial-gauge type extensometer to measure the extension over the joint. The permanent set method was used to determine the 1°/o and 2°/o proof loads, and the ultimate loads were also found.

Results

The 1°/o and 2°/o proof loads and ultimate loads are tabulated for 1/8" dia. rivets in table 1, and for 5/32" dia. rivets in table 2. These are plotted in fig. 3 but reveal considerable scatter. The curves on this fig. are obtained as mentioned below. The manufacturer's figures are also reproduced, showing favourable comparison. The nominal shear and bearing stresses (based on measured thickness of sheet) and the ratio of shear area to bearing area, A/dt, have been calculated. The shear stress is then plotted against the area ratio (fig. 4) for each case (1°/o and 2°/o proof and ultimate loads for single- and double-shear). This representation is found to give least scatter, while ostensibly representing the measured quantities, so that mean curves can best be drawn. Little weight has been placed on the early results for 1/8" dia. rivets as they appear to have wide and irregular scatter, with low strengths. Investigation has shown this to be due to incorrect hole size.

The plots of fig. 4 are essentially a representation of the strength of the joint (compensated for rivet size) against diameter/single sheet thickness ratio.

The results are plotted in fig. 5 as nominal shear- to bearing-stress. This representation permits an understanding of the differences between single- and double-shear to be seen more clearly.

Finally, the ratio of double-shear to single-shear strength is plotted in fig. 6 as a function of the thickness/diameter ratio. These curves have been obtained from the mean curves of fig. 4.

For an understanding of these curves, the joints must be divided into three classes as in fig. 2: those which fail primarily in shear, in bearing, and by tearing. The first class obtains for values of A/dt less than 1.5 and was characterised by double-shear strength deteriorating with increasing thickness. While the proof stresses for both types reach a similar maximum shear stress (the proof for the rivet or sheet material), the double-shear joint shows a loss of strength below this for increased thickness. This is not apparent in the ultimate strength. The cause of this would appear to be bending of the rivets within the inner sheet causing increased extensions, though not affecting the ultimate loads. This would be aggravated as rivet length increases, due to decreasing " tie-rod" effect (the restraint due to tensile load). The divided inner sheet used in these tests in the double-shear joints would falsely weaken the restraint on rivet bending, so that it is doubtful whether this effect would be as marked in practice. It is significant to note that this behaviour can be detected in the results for the solid rivets, though the bending strength of a mandrel rivet would be less than that of a solid one.

In the second class of joints (for A/dt between 1.5 and 5), where failure is primarily due to bearing, the strength in double-shear is considerably greater than in single-shear. The elongation of hole and crushing of rivet due to high bearing stresses would result in an ill fit which would have a more severe effect in single-shear than in double-shear. The stability of the rivets in the latter, would restrain deformation by tilting of rivet and ultimate failure by pulling through of the rivet head or tensile failure of the rivet. A crushing of the rivet would be more serious in mandrel rivets (where the sheath is more ductile than the mandrel), than in solid rivets.

The third class, of tearing failure (for A/dt greater than 5), is again characterised by a deterioration of double-shear strength. In a single-shear joint, tilting of the rivet would cause slight stress concentrations at the inner bearing edges of the holes, but some of the load would be taken as a tensile load in the rivet and reacted over the area under the heads, thereby alleviating the bearing stresses and so the onset of tearing. The fact that the bearing stresses in single-shear are lower than those in double-shear is obvious in fig. 5. The ultimate strength would be similarly affected as the proof strengths, since for thin sheet the tearing strength would be less than the "pull-through" strength. This effect would occur with any type of rivet, to a greater or lesser extent, as found with solid rivets.

Finally, the results of the tests on effect of fit are presented diagramatically in fig. 7, where an appraisal of the manufacturer's recommendations may be made. It is obvious that it is important to take heed of these. The reason for a great variation of strength with fit is that the mandrel rivet is self expanding to fill the hole, and this can only be useful within a reasonable limit. Oversize holes would not be filled, and undersize holes would result in a broaching of the rivet, separation of sheets or poor gripping by the rivet.

Conclusions

Over a useful range of thickness/diameter ratios, the double-shear strength of Avdel riveted joints is better than the single-shear.

It is extremely important with a self-fitting rivet to follow correct manufacturing procedure.

The strengths of the joints compare favourably with quoted figures.

References

1. Handbook: "Avdel Self Sealing Blind Riveting System". Aviation Developments, Ltd. High Holborn, London.

2. Howe, D. Double shear strength of BS L69 Snap Head Rivets in L72 and L73 Aluminium Alloy Sheet - Co A Note 50.

References (contd.)

3. Ripley, E.L. Strength of BS L 37 Snaphead Rivets in DTD 546 Aluminium Alloy Sheet - R.A.E. Tech Note, Struct. 104.

TABLE I

Experimental Results: 1/8" Dia. Rivets.

Thickness		Single Shear			Double Shear		
Nom.	Actual	r_{10}	r_{20}	R	r_{10}	r_{20}	R
26 G	.019	298	333	454	745	815	998
26 G	.019	375	407	457	837	885	1004
24 G	.022	330	378	450	507	790	1062
24 G	.022	460	495	510	970	1030	1126
22 G	.028	346	420	553	975	1140	1648
20 G	.037	390	532	730	1230	1480	1841
18 G	.052	510	682	906	1060	1485	2100
18 G	.048	714	783	857	1640	1750	2020
16 G	.063	508	732	1002	1270	1675	2200
14 G	.082	540	700	1030	807	1210	2178
14 G	.082	812	887	996	1370	1590	2093
14 G	.082	625	715	925	-	-	-
14 G	.082	820	885	984	-	-	-
14 G	.082	330	620	1018	-	-	-

Notes:

Recent results.

Different fits - drill sizes: 1/8" (.1250); No.30 (.1285); No.29 (.1360).

TABLE II

Experimental Results: 5/32" Dia. Rivets.

Thickness		Single Shear			Double Shear		
Nom.	Actual	r_{10}	r_{20}	R	r_{10}	r_{20}	R
26 G	.020	415	478	557	1010	1090	1158
24 G	.022	548	605	668	917	1017	1440
24 G	.022	-	-	-	1215	1275	1413
20 G	.037	741	781	982	-	-	-
20 G	.038	770	830	940	1850	2040	2400
18 G	.052	1000	1093	1200	2480	2685	3140
14 G	.082	1150	1325	1648	2700	2970	3282
12 G	.105	1290	1435	1723	2460	2840	3590
12 G	.105	1085	1310	1720	-	-	-
10 G	.125	1200	1415	1773	1780	2460	3410
10 G	.127	1400	1510	1780	2000	2560	3500

Notes:

Recent results.

Different length rivets: long (type 514); short (type 510)[1]

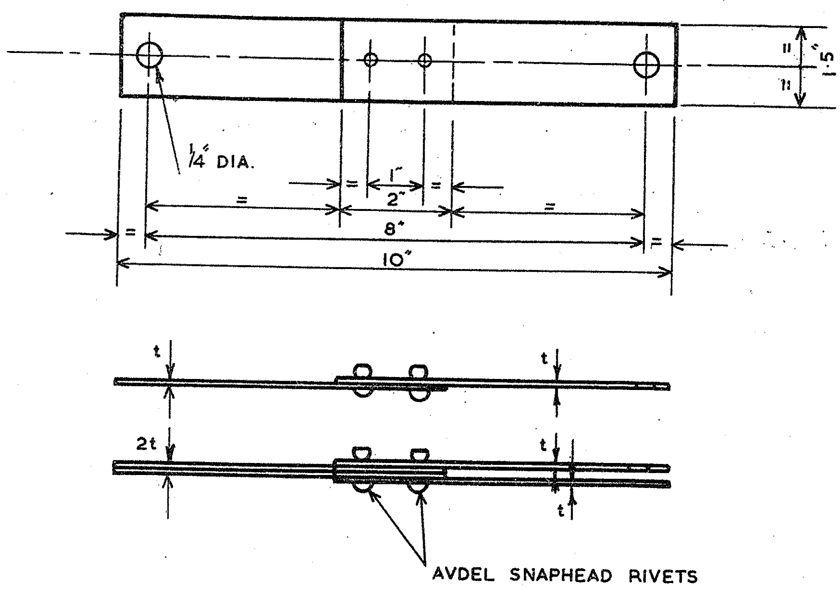

FIG. 1 DETAILS OF SPECIMENS

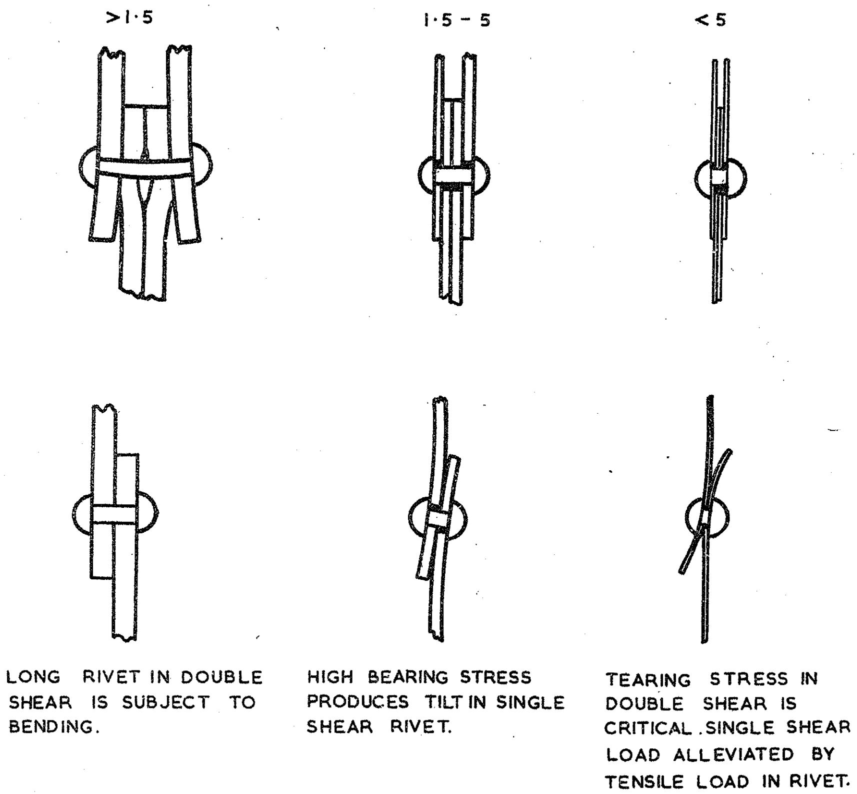

FIG. 2 CLASSES OF JOINTS SHOWING DIFFERENCES IN BEHAVIOUR FOR RANGE OF A/dt VALUES.

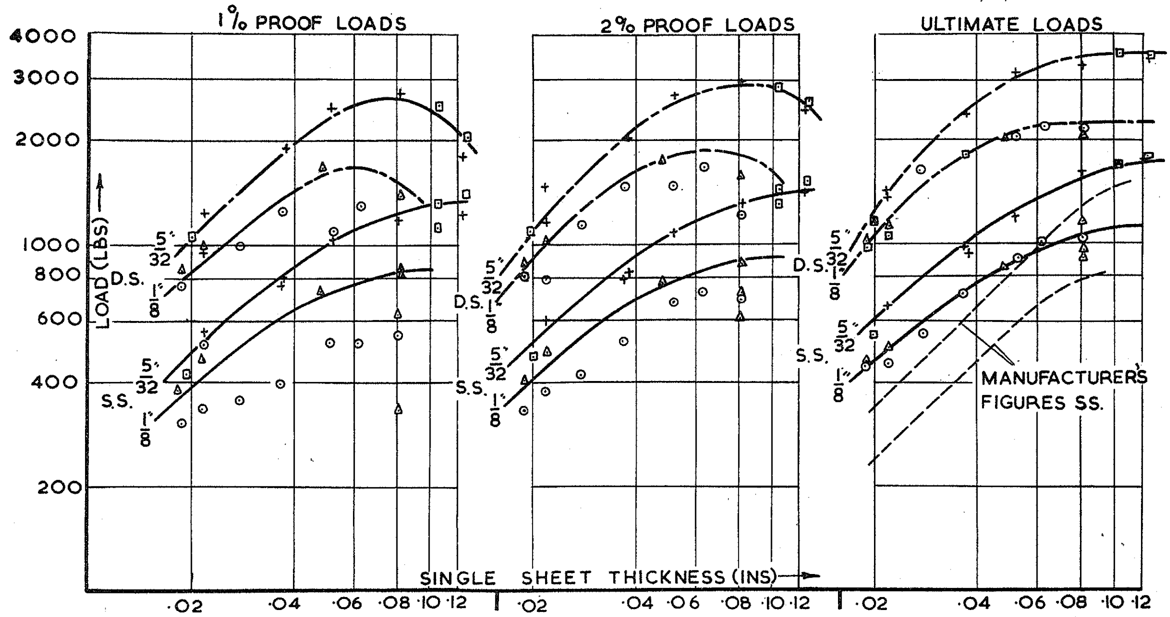

FIG. 3 STRENGTH OF AVDEL RIVET JOINTS (2 RIVETS)

(CURVES DERIVED FROM FIG. 4)

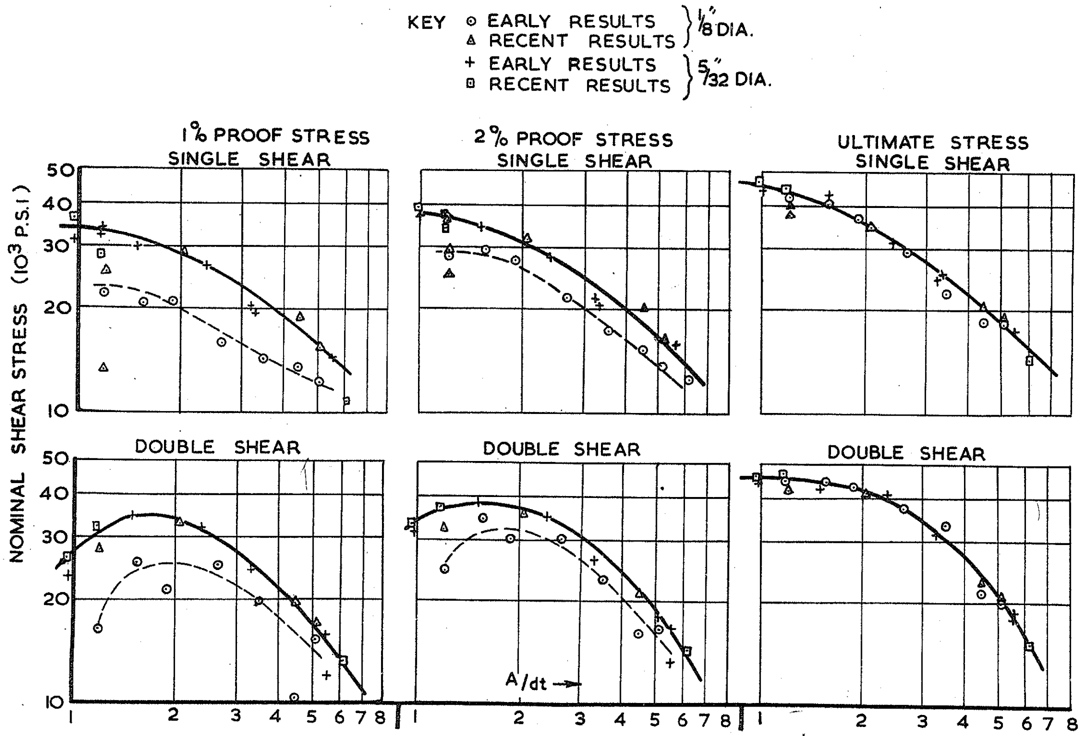

FIG. 4 NOMINAL SHEAR STRESSES & AREA RATIO PARAMETER

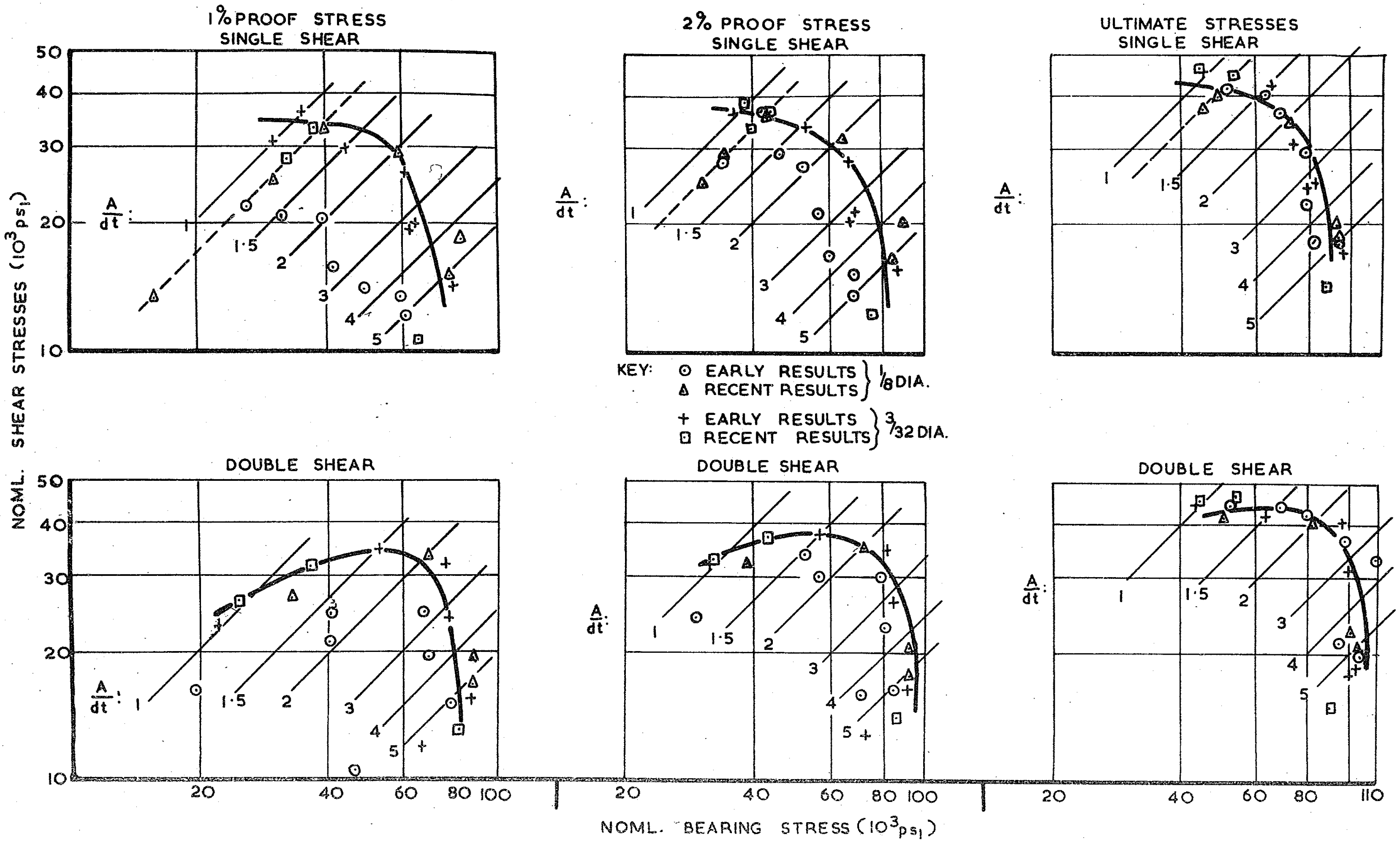

FIG. 5 NOMINAL SHEAR AND BEARING STRESSES
(CURVES DERIVED FROM FIG. 4)

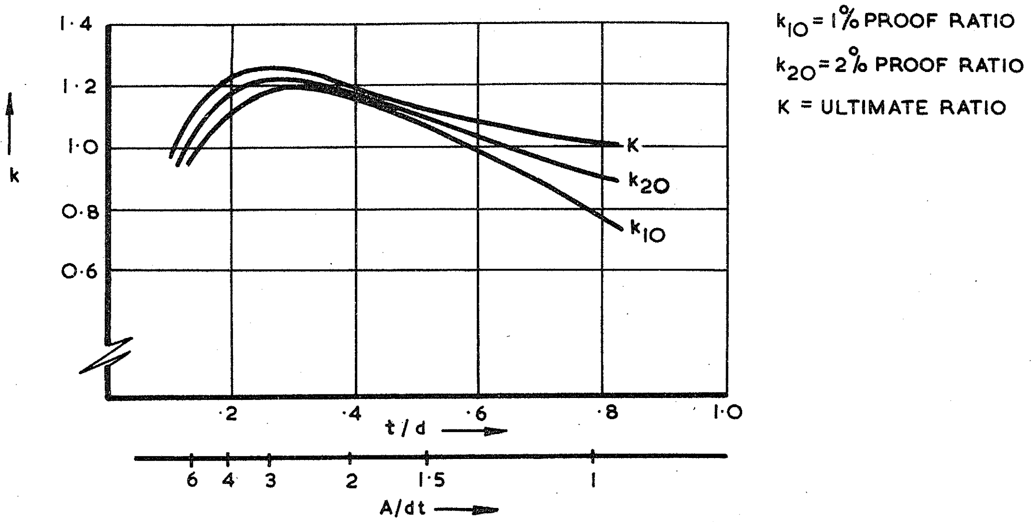

FIG. 6 RATIOS OF DOUBLE TO SINGLE SHEAR STRENGTHS FOR 1% AND 2% PROOF AND ULTIMATE CASES.

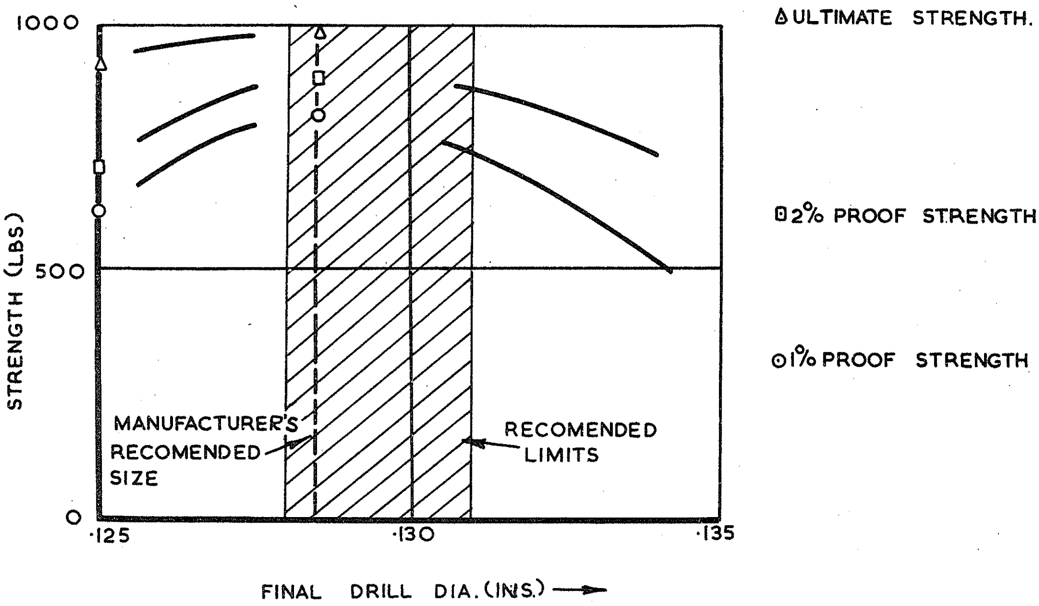

FIG. 7 EFFECT OF FIT ON STRENGTH OF AVDEL RIVET LAP JOINT IN SINGLE SHEAR (2 : 1/8" DIA. RIVETS 14G. DTD546 B SHEET)